mere teaching, may be undertaken (such a one as is found at universities, *de facto*) cannot be carried on properly and successfully by less than three persons. The highest officer must be the responsible director, — a man of superior ability, extensive attainments, and prolonged experience: one, in short, who has mastered his department of science, knows its possibilities and deficiencies, and is therefore capable of judging what work is most feasible and instructive for students, and what problems are best adapted for investigation. It is sheer waste for a man of such high capacity to sacrifice his whole time to the arrangement of apparatus, or the preparation of experiments for his lectures or his students: therefore it is desirable, we prefer to say indispensable, that he should have an assistant, preferably a young devotee of science, who will be fitted by his experience as an assistant to ultimately become himself director of a similar laboratory. The third person is the laboratory keeper (*diener*), who needs must be a man of some mechanical skill, so that the precious instruments may be safely intrusted to his care. He should be something more than a servant, and less than an assistant. A laboratory without this working-force cannot do much for the promotion of science, although even more modest ones may be valuable for simple instruction. A first-class laboratory, and in Germany are many such, has always a larger number of officers. There are few persons among us who appreciate the magnitude of a scientific laboratory: were it otherwise, there would not be so many petty substitutes for them.

Existing laboratories fulfil two functions, — giving education to students, and opportunity to investigators. The multiplication and enlargement of laboratories depend chiefly upon the growing recognition of the truth that first-hand knowledge is the only real knowledge. The student must see, and not rest satisfied with being told. Translated into a pedagogic law, it reads, 'To teach science, have a laboratory; to learn a science, go to a laboratory.' He who has never learned to appreciate a laboratory in its highest sense does not know even the meaning of 'I know.' We do not consider those liberally educated who have never had even a single thorough course of laboratory training. It is the laboratory which gives strength to the movement in favor of scientific education, for it opens to all the road to real living knowledge; while books by themselves lead off to the by-ways of what other men thought they knew at the time they wrote. Life and death are not more different than are, in their ways, real and book knowledge of nature. A book, at best, is but a useful adjunct in science.

To the investigator the laboratory is, or ought to be, all in all, providing him with every thing wherewith to experiment and observe. Not only should there be on hand all the paraphernalia of research, but it must also be possible to purchase or construct the new apparatus which may be devised to meet the new requirements. Yet in no respect, perhaps, do laboratories maintain a more efficient utility than in fostering technique, by the development of new methods, and by gathering from all sources complete information concerning the available processes and means of work. Only the daily laborer at science can adequately value the knowledge of methods which is concentrated in every well-managed laboratory. In places where these requirements are fulfilled, discovery makes rapid progress; and their existence explains the present immense rapidity of scientific progress.

What a contrast between the magnificent opportunities we enjoy to-day and the meagre possibilities of fifty years ago! The change has been rendered possible by the establishment of well-fitted laboratories for the promotion of science.

TESTS OF ELECTRIC-LIGHT SYSTEMS AT THE CINCINNATI EXPOSITION.

The commissioners of the eleventh industrial exposition held in Cincinnati in September and October, 1883, determined to undertake a series of tests of the efficiency of electrical lighting systems, and so advertised in their circulars, which were widely distributed. Special premiums were offered for the best system of arc-lighting, the best system of incandescent lighting, the best dynamo machine for arc and incandescent lighting respectively, and for the best lamp in each system.

A jury was appointed by the commissioners, consisting of T. C. Mendenhall, chairman, H. T. Eddy, Thomas French, jun., and Walter Laidlaw. The jury was instructed to make such tests and measurements as seemed desirable and were possible under the circumstances, and which would aid in arriving at a verdict upon the relative merits of the different exhibits.

The opening of the exposition took place on Sept. 5, and the close on Oct. 6. The jury was requested to make its report of the awards one week before the close of the exposition.

In response to the proposal of the commis-

sioners, four systems of electric lighting were entered for competition. The Thomson-Houston electric-lighting company submitted a system of arc-lighting; the Edison electric-lighting company, a system of incandescent lighting; and the U. S. electric-lighting company offered a system of arc-lighting, and also one for incandescent lighting. Several things conspired to make the tests less complete in some respects than was desired by those interested. The members of the jury were all engaged in professional work, and were therefore unable to devote their entire time to the tests. The dynamometers used were built after the exposition opened, and were not completed until after many vexatious delays. One of them, that upon which the most reliance was placed, was of a form recently devised, and the principles of which had never been realized in practice, except in an experimental model constructed by its inventor. Its construction on a large scale necessarily involved a good deal of experimentation. In spite of these delays, the jury was enabled to begin regular work on the evening of Sept. 25, and to make, during the succeeding ten days, such tests of the most important features of the various systems as to justify them in making the awards, whatever difference might have existed in reference to minor points, which, for lack of time, were not thoroughly investigated.

The plan adopted was substantially that upon which nearly all similar trials have been conducted. The energy consumed by the dynamo was measured by means of the dynamometers, and the electrical energy in the circuit was determined by well-known methods. This gave the efficiency of the machine as a generator. The illuminating-power of the lamps was compared, and at the same time the electrical energy which they consumed was measured. A combination of the results obtained by these two processes gives the relative illuminating-power per unit of energy consumed by the dynamo, which represents the relative commercial efficiencies of the systems. The measurements made, therefore, were of three kinds, — dynamometric, electric, and photometric; and they will be considered in the order mentioned.

Dynamometric measurements.

Two separate dynamometers were simultaneously employed in measuring the mechanical energy expended in running the armatures of the four dynamos which were tested. They have been called, from the manner of their operation, the 'belt' and 'cradle' dynamometers respectively.

The belt dynamometer has been frequently employed before; and its manner of operation is explained by Dr. Hopkinson in *Engineering*, vol. 27, p. 403, where he gives a figure of it, and the formulae used by him in determining the power expended in certain electric-light tests. These formulae tacitly assume that the belt is perfectly flexible and without weight: for otherwise terms must be introduced into the formulae to take account of the differences of tension in the belt caused by passing the dynamometer-pulleys, and the centrifugal force generated in the belt as it leaves the various pulleys. The velocity of the belt being great, it is more than probable that such terms are required in order to deduce accurate results from this form of dynamometer.

Under these circumstances the computation of the power expended from the observations of the belt dynamometer by the theory as at present known was wholly unsatisfactory, giving results, in all except the first few tests, considerably less than the truth, and in some cases less than the electrical power in the circuit.

The cradle dynamometer, however, gave results of a much more satisfactory character. The principle of this dynamometer is a recent invention of Professor Brackett of Princeton, N.J., and, owing to its novelty and great accuracy, merits a somewhat minute description. It was built at the machine-shops of Messrs. Lane & Bodley, Cincinnati, under the superintendence of Mr. Laidlaw, from designs made by Mr. Eddy, to whom is due the arrangement of its various parts.

It consisted of a substantial platform, *cc*, fig. 1, seven feet long by four and a half feet wide, hung at each end by iron rods, *ee*, from an axis consisting of a short piece of two-and-a-half-inch shafting, *a*, which rested upon a supporting-girder, *gg*. Fig. 1 represents the framework, etc., at one end of the platform, to facilitate raising and lowering the girder *gg*, which carried the platform *cc* by means of the jackscrews *jj*, upon which *gg* rests. The uprights *bb* are guides passing through the openings *bb*, shown in fig. 2, which is intended to represent the ground-plan of *gg*, and adjacent parts of the cradle. Each girder, *gg*, was composed of two planks, held at a distance of three inches apart by blocks, *dd*, and bolted firmly together. The rods *ee* passed between the planks *gg*, and were forged to an eye which fitted the axis *a*. The axis *a* rested upon pieces of smooth boiler-plate in the upper surface of *gg*.

The uprights *bb* form part of a rigid framework, well bolted together, one side of which is seen in outline on a smaller scale in fig. 3.

A scale-beam, *ff*, made in the form of an inverted L, and graduated to fractions of an inch, had the lower extremity of its vertical arm fastened to the platform *cc;* while at the angle was an eye which was centred upon *a* by the screws *iii*.

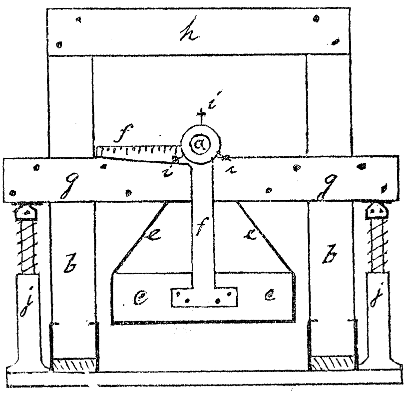


FIG. 1.

It is readily seen that the platform, when it was raised from the ground, as shown in fig. 1, was free to swing through a limited space, either to the right or left, and that any eccentric weight or force so applied as to tend to swing it to the left could be compensated by a weight upon the scale-beam, *ff*, which swings with it; so that the platform could be still kept in its horizontal position.

The axis about which the swinging tends to occur is the line of contact between *aa* and *gg*, which line we shall for brevity henceforth call the axis *aa*.

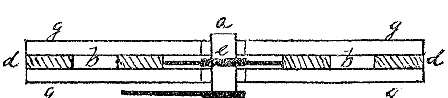


FIG. 2.

In setting up the dynamometer, it was so placed that the axis *aa* was directly below the axis of the driving-pulley, and in the same vertical plane with it. The dynamo to be tested was placed upon the platform *cc*, while *cc* was resting upon the ground; and it was blocked up on *cc* to such a height, that the axis of the armature was as nearly at the same height as the axis *aa* as could be readily done by direct measurement. This adjustment could be effected with all necessary exactness once for all; for, even though the armature were slightly above or below the axis *aa*, no error would thereby be introduced into the observations.

The axis of the armature was also set, as nearly as it could be conveniently, in line with the axis *aa;* but the final adjustment, so that the centre of the armature-pulley was neither to the right nor left of the axis *aa*, was made mechanically as follows. The platform and dynamo were raised from the ground, and the girders *gg* carefully levelled by means of the jackscrews. The platform was then brought to a horizontal position by placing compensating weights upon it. The belt was next adjusted, and was tightened by lowering the platform. It was then found, that, in case the axis of the armature was to the right or left of *aa*, the tension of the belt exerted a force to tip the platform, and it no longer stood horizontal. This was corrected, — one half, by shifting compensating weights; and the other half, by moving the dynamo to the right or left. The belt was then slackened by raising the platform, and a similar adjustment again made to bring the platform to the horizontal position. This was repeated until the platform stood horizontal, whether the belt was tight or loose; both girders being at the same height, and both accurately levelled, account being taken of the bending.

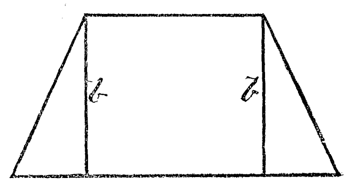


FIG. 3.

A further application of compensating weights was employed to render the balance sensitive. With the Edison dynamo, which is top-heavy (i.e., its centre of gravity is above the axis of the armature), more than a ton was hung on the sides of the platform to bring the centre of gravity of the whole down to the axis *aa*. With the other dynamos, whose centres of gravity are below the axis of their armatures, compensating weights of smaller amount were placed upon a staging built on the platform above the dynamos, in order to bring the centre of gravity of the whole up nearly to the axis *aa*.

In making the tests, the power was applied to turn the armatures clockwise in fig. 1. This caused the horizontal scale-beam *f* to rise; and weights were placed upon it to bring it back to the horizontal position. The moment of

the couple, got by multiplying the weight so applied by its distance from the axis *aa* as read upon the scale-beam, is evidently equal and opposite to the moment of the couple with which the armature is turned. Thus the moment of the force applied to run the armature was measured in foot-pounds. This moment, multiplied by the number of revolutions per minute and by 2π, is the work expended in driving the armature, in foot-pounds per minute.

It was found convenient to use a weight having a moment somewhat less than sufficient to bring the scale-beam to the horizontal, and employ a Chattillon spring-balance with a dial-face reading to 2 oz. to furnish the remaining part of the couple. This balance was fastened to a vertical cord passing around a small winch, which enabled the observer to bring the scale-beam to the horizontal with facility.

The principal difficulty to be apprehended in testing with this dynamometer was a possible tendency to oscillation, which might be caused by running the belt. Had this existed, it might have been checked by a dash-pot; but the weight of the platform and dynamo was sufficient to almost entirely obviate any such difficulty, and give very considerable steadiness of position. Indeed, the jarring seemed to increase its sensitiveness, and evidently enabled the platform to come to rest in its position of equilibrium by overcoming any initial friction existing.

The structure was mostly built of three-inch plank, ten or twelve inches wide. The platform was designed to safely carry five tons at its centre.

For permission to make use of the cradle dynamometer, the jury is indebted to the kindness of Professor Brackett.

In addition to the use of the two dynamometers described, indicator-diagrams were taken from the steam-engine furnishing the power for driving the dynamo machines. Throughout the dynamometric tests the machines were driven by a Cummer engine of about a hundred horse-power, which furnished power for other dynamos than that upon the cradle, as well as for two or three pieces of machinery on exhibition in Power Hall. It was thus impossible to make the taking of indicator-diagrams contemporaneous with the regular tests, owing to the large load which the engine carried; and they were generally taken after ten o'clock at night, at which hour the remainder of the load was thrown off. Although these indicator-cards were not used in the final computations, they furnished valuable checks upon the performance of the dynamometers.

The electrical measurements.

For the purpose of making the electrical measurements as free from disturbance as possible, a small room, about twenty feet long and ten feet wide, was fitted up in the basement of the central part of the large exposition building. In this, three brick piers were built upon solid foundations, and two or three wooden brackets were firmly secured to the walls, so as to furnish firm resting-places for the galvanometers. The main lines of the arc-lighting systems were run through this room, and very heavy copper conductors connected the room with the space in which the dynamos were exhibited; so that the entire current from the incandescent machines could be introduced when desired.

The electric measurements consisted in the determination of the strength of the current, and the electromotive force between two points in the circuit. For this purpose several galvanometers of different kinds were employed. For the measurement of current strength the principal instrument used was one of Sir William Thomson's current galvanometers, made by White of Glasgow. Although of recent invention and construction, the instrument is probably so well known as not to require any detailed description. It consists essentially of a magnetometer, and a coil of very low resistance. In the magnetometer four short magnets are combined to form a needle, the position of which is indicated by a very light yet very rigid aluminum index. A steel magnet, bent in the shape of a semicircle, is placed in a vertical plane over the needle, so that the latter is approximately at the centre of the circle of which the magnet forms a part. One end of the magnet is furnished with a cross-piece of brass, from one extremity of which projects a pin which rests in a conical hole, and upon the other extremity is a 'button;' so that freedom of motion around the pin as an axis is allowed. The opposite end of the magnet rests in a groove cut around the end of a screw, by the movement of which the plane of the magnet can be shifted towards the east or towards the west.

The coil is fixed in a vertical plane at one end of a wooden table whose length is about one foot, and breadth about five inches. The table is furnished with levelling-screws, and a V-groove is cut lengthwise through the centre, at right angles to the plane of the coil. In

this groove the magnetometer, with its attached magnet, slides; so that, by placing the needle at different distances from the centre of the coil, the instrument may be used for measuring currents differing very greatly in strength.

The adjustment of the instrument consists in placing the magnetometer upon the table, without the field-magnet, and adjusting the whole so that the index is at zero of its scale; after which the magnet is put in its place, and, if necessary, one end is moved by means of the screw until the index again points to zero.

The interpretation of the reading of the instrument is a very simple operation. A scale along the edge of the V-groove shows the position of the magnetometer. It is necessary to know the strength of field at the needle, which is, of course, that due to the magnet, plus the horizontal component of the earth's magnetism; and then, if this strength of field in C.G.S. units be multiplied by the reading of the needle, and divided by the scale-reading of the magnetometer, the result will be the current in ampères.

This galvanometer was permanently mounted on one of the stone piers, and its connections were so arranged that it could be quickly thrown in or out of the circuit without interfering with the continuity of the same. The direction of the current through the galvanometer could be instantly reversed; and throughout the observations reversals were regularly made, so as to eliminate error arising from displacement of the zero. The zero-point was adjusted, however, at the beginning of every series of observations, and examined at frequent intervals during the same.

A differential galvanometer was also used in measuring current strength. This instrument was kindly loaned to the jury by Professor Brackett of Princeton, by whom it was devised and constructed. A description of it will be found in the *American journal of science*, vol. xxi. p. 395. It consists essentially of two heavy rings, one within the other, through which the current goes in opposite directions. The needle in the centre has a silk-fibre suspension. The radii of the rings being given, the constant of the instrument can be readily calculated. It was especially constructed for the measurement of strong currents, ten ampères giving a deflection of fourteen to fifteen degrees when the value of H is a little more than .2. When the current was steady, it behaved admirably; but with a fluctuating current it became extremely difficult to get trustworthy readings, owing to the constant vibration of the needle. The graduated circle was so small that the estimation of fractions of a degree was quite uncertain. Even with steady currents, more time was required for reading the Brackett than the Thomson, owing to the length of time needed for the needle to come to rest after a reversal of current. For these reasons its use was not continued throughout the test. It was observed continuously during the tests of the Thomson-Houston dynamo, and during a part of the tests of the Weston dynamo, when, owing to fluctuation in the current, its use was necessarily discontinued. It served a useful purpose, however, as a check upon the indications of the Thomson instrument, the close agreement of the two justifying confidence in the indications of the latter. The most carefully made series of comparisons was that of Sept. 20. During the afternoon of that day, eight simultaneous readings of the two instruments were made; the current, which was remarkably steady, being furnished by the Thomson-Houston dynamo. The means gave 9.92 ampères as indicated by the Thomson, and 9.93 ampères for the Brackett. The regular tests were begun on Sept. 25, and in the mean time several additional conducting-wires had been brought into the testing-room. The indications of the Brackett galvanometer were, after this, constantly somewhat less than those of the Thomson, which was doubtless due to the alteration of the field by the presence of the currents. The difference was quite constant, and amounted to about two per cent. Thus, on Sept. 25 the Thomson gave 9.97 ampères, and the Brackett 9.77. On the 26th the Thomson indicated 10.0, and the Brackett 9.80, and on the 27th, with the Weston arc dynamo, showed 18.6 ampères, and the Brackett 18.3. That this discrepancy could be accounted for by the effect of the current upon the strength of field was established by vibrating a needle under two conditions, — with and without the currents. Herein is shown the advantage of a strong, permanent magnetic field, such as exists in the Thomson instrument. An alteration of the field, which might considerably influence the results from the Brackett, would hardly be perceptible with the Thomson.

During the tests of the arc-light machines the whole current was taken through the galvanometers. With the incandescent systems, however, in which the current was sometimes as high as 170 ampères, this was impossible; as the coils and connections would have been greatly heated. The current might possibly have been safely divided between four or five instruments; but, these not being at hand, it became necessary to make use of a shunt.

For this purpose the heavy main conductor was cut, and the two ends were inserted into large mercury-cups, cut out in a block of wood an inch and a half thick. These cups were also connected by about forty feet of number 0 copper wire, the ends of both main and shunt wire being well immersed in the mercury, and pressed close together. These mercury-cups were connected with two others by means of short copper wires, and into the second pair the ends of the galvanometer wires were plunged. As thus arranged, about one-fifth of the current was taken through the galvanometer. Even with this division of the current, it was found, that, when using the strong current from the Weston dynamo, the wires of the galvanometer were somewhat heated; and in order to avoid this result, a short piece of number 0 wire, not more than two or three inches in length, was bent so that it could be inserted in the mercury-cups, and thus cut the galvanometer out, except during the few moments necessary for taking a reading. During all of the 'resting' periods this short wire carried by far the greater portion of the current, and thus tended to prevent the heating of the shunt wire proper as well as of the galvanometer.

The determination of the ratio of the two parts into which the current was divided, or the value of the 'shunt multiplier,' was, of course, a matter of great importance. In the preliminary measurement of this ratio the current from the Thomson-Houston machine was of great service on account of its steadiness. To begin with, a number of tests were made to discover if the connection resistances were of such importance that any accidental variation in them would perceptibly alter the shunt ratio. The shunt was repeatedly lifted out of the cups and replaced, and the galvanometer connections were broken and remade. Every thing that could be disturbed was disturbed; but, upon reconstruction, the result was found in all cases to be practically unaltered. On Sept. 28 a series of twenty measurements was made with the shunt alternately in and out, using a current of 10 ampères. The results agreed closely with each other, and gave 4.6 as the value of the shunt multiplier. On the following day the tests of the incandescent machines began; and the shunt was not moved from its position, nor disturbed, until after the conclusion of the entire work. On Oct. 3, after all of the regular tests had been completed, another test of the shunt was made, with a current of 10 ampères, as before. Ten observations were made, all of which agreed in giving a ratio of a little more than 5.0. This result was quite unexpected, and the discrepancy between it and that obtained from the first test was entirely too great to be accounted for by errors of observation. As circumstances prevented further tests in Cincinnati, it was determined to remove the shunt and all connections to the physical laboratory of the Ohio state university, where a thorough examination of the cause of the difference could be made. This was done; but, before any experimental examination had been undertaken, the origin of the difficulty suggested itself. The two short wires connecting the mercury-cups had been in one case thrown with the galvanometer doubtless, and in the other with the shunt. It was perfectly certain, however, that throughout the tests they had formed a part of the galvanometer. Upon examination, this explanation was at once found to be correct. The shunt and galvanometer were connected up precisely as they had been in Cincinnati: and a series of twenty-five observations gave, when the small wires were a part of the shunt, a multiplier of 4.60; and, when they formed a part of the galvanometer circuit, it was 5.01. The measurements were made by comparing the resistance of the two parts of the circuit by means of the fall in potential, as shown by a Thomson's reflecting galvanometer of high resistance. While in use in Cincinnati, the shunt was constantly carrying a portion of the current; and its temperature was therefore always slightly higher than that of the galvanometer. The difference was small, and it could not be measured accurately; but, on account of its existence, it was thought proper to adjust the shunt multiplier. An excess of heat in the shunt would throw a greater amount of the current through the galvanometer than would go there if the two were at the same temperature: accordingly, the value accepted was 4.9 instead of 5.0, as indicated by the comparison, in which the currents used were much weaker than those transmitted during the tests. It will be observed, the existence of an excess of temperature in the shunt favors somewhat the system in which the stronger current was transmitted.

In the measurements of electromotive force, Thomson's potential galvanometer, by White, was used. In the beginning a large number of comparison observations were made, in which the same electromotive force was measured by this instrument and by the well-known method of discharging a condenser through a high-resistance galvanometer.

A condenser of one-half micro-farad capacity, and a reflecting galvanometer of nearly seven thousand ohms resistance, both by Elliot Broth-

ers, were used with a battery of ten Daniell cells in good condition. These comparisons proved that the indications of the potential galvanometer could be relied upon as trustworthy within practical limits, and in the actual tests it alone was used on account of the greater convenience and rapidity with which observations could be made. Further tests of its accuracy were made, however, which will be referred to later. It is sufficient to say, that this instrument, in form and construction, is quite similar to the current galvanometer already described, except that the coil has a resistance of nearly seven thousand ohms. A key is placed in the circuit, so that the current passes through the coil only during the few moments necessary to secure a reading, thus preventing the heating of the coil. The difference of potential in volts, between the two points to which the leading wires are connected, is found by the same process as is used for reducing the readings of the current galvanometer to ampères. In measuring the efficiency of the dynamos, wires were brought from their binding-posts to the galvanometer. In the arc-light machines the electromotive force was high, amounting to more than twelve hundred volts in the Thomson-Houston dynamo; and it was therefore desirable to introduce extra resistance in the galvanometer circuit. From resistance-boxes made by Elliot Brothers, an amount equal to seventeen times the resistance of the galvanometer was thrown in, thus bringing the fall in potential in the galvanometer within easy range. Great care was taken to see that the coils were not heated during these measurements; and for this purpose the boxes were opened, and the coils exposed to the air, frequent examination being made to see that no rise in temperature took place. Precisely the same arrangement existed throughout the tests of both arc systems. During the photometric tests the wires of the potential galvanometer were attached directly to the lamp under test, so that the fall in potential through the lamp only was measured.

Photometric measurements.

Unquestionably, the most difficult question to deal with, in work of this kind, is the question of photometry. The expression of illuminating-power in 'candles' is a matter of great uncertainty, arising from the uncertain character of the standard, and also from the great inequality existing in the intensity and composition of the lights which are brought into comparison. As the test was intended to be purely competitive, the jury decided to ignore the question of 'candle-power' entirely, and confine itself to a comparison of the lights under consideration. It is believed that the adoption of this plan rendered the results free from many errors to which they would otherwise have been liable.

The photometric comparisons were made by means of the ordinary Bunsen disk photometer, as modified by Letheby. Some preliminary experiments were made with one of Glan's spectrum photometers, for the use of which the jury was again indebted to the kindness of Professor Brackett. The adjustments of this instrument are delicate, and observations cannot be made so rapidly with it as with the ordinary disk photometer; so that, in consideration of the limited time at the disposal of the jury, it was decided not to attempt its general use throughout the tests. It was hoped and intended, in the beginning, to make a thorough examination of the composition of the different lights; but unforeseen delays in the preparation of other portions of the machinery of the test forbade this. As the candle was not made use of, all the lights which were compared were more nearly of the same composition, and thus much of the difficulty in the use of the disk photometer did not appear.

It was found most convenient to make the comparison of the arc-lights through one of the incandescent lamps, as the steadiness and constancy of these could be depended upon during the time necessary for a comparison. In these measurements, a long gallery in the basement of the main building, and adjoining the testing-room, made it possible to place the two lights which were being compared at a distance of fifty feet from each other. The line extended into the testing-room, where the photometer-bar, ten feet in length, was placed. An Edison incandescent lamp, nominally of sixteen candle-power, was used as a standard. In the first series of experiments, comparisons were made with the arc-lamps in three different positions; five readings of the position of the photometer-box and of the galvanometers being made at each position. The lamp was first suspended in its normal, vertical position; then afterwards it was inclined at an angle of forty-five degrees, first with its base away from the photometer-box, and afterwards with its base towards the same. After such a series had been completed with one of the two lamps in competition, it was at once removed, and its place was supplied by the other. On the following night the comparison was continued, other lamps having been selected; but the lamps were tested in only two

positions, — the normal position, and that in which the base of the lamp was towards the photometer-box; these being regarded as the positions of the greatest importance. Altogether, twenty-five photometric observations were made in comparing the arc-lamps. The lamps compared were taken at random from those in use by the exhibiters.

The comparison of incandescent lamps presents questions of far greater delicacy and difficulty. There is one element, in the economy of an incandescent lamp, which does not enter to any extent in the consideration of arc-lamps; that is, the life of the lamp. Although of great importance, it did not seem possible, in the limited time which was at the disposal of the jury, to investigate this point. The only fair and impartial method of making such an investigation, involved, in the opinion of the jury, the continuous and prolonged burning of a large number of lamps belonging to the different competing systems. Under the circumstances, it was absolutely impossible to make use of this method.

There exists, also, difference of opinion as to the proper method of comparing the efficiency of two incandescent lamps. They may be reduced to the same illuminating-power, and the electrical energy consumed by each may be compared; they may be brought to a condition in which they consume the same electrical energy, and their illuminating-power compared; or they may be allowed to differ in both of these elements, and comparisons be made in both.

The first method has been pursued in several tests which have been made both in Europe and in this country.

Incandescent lamps are generally made to be equal, nominally, to a given number of standard candles; but, by modifying the consumption of energy, a lamp of nominally low candle-power can be made to produce almost any degree of illumination, from nothing up to the equivalent of several hundred candles, the high illumination being, of course, at the expense of the life of the lamp. If this element is left out of consideration, the efficiency of a lamp increases rapidly with its degree of incandescence. As it is by no means necessary that incandescent lamps should run at a fixed 'candle-power,' it will follow that the temperature at which a lamp will show greatest efficiency (including the life element) will depend greatly upon its construction.

Taking two lamps of radically different construction, however, there will be for each a certain set of conditions as to current strength and electromotive force, and including the element of life, under which it would show its highest efficiency and economy. After such conditions were determined for each lamp, a strict comparison would be possible. The reduction of two such lamps to the same degree of illumination would probably be unfair to one or the other, or possibly to both, if the element of life is not considered.

Suppose that a lamp in one system is at its best, *all things considered*, at fifteen candle-power, and that one in another reaches its highest degree of efficiency at sixteen candle-power. If they are both brought to fifteen candle-power, the second must suffer in the comparison; and if both are brought to sixteen candle-power, *and the element of life is not considered*, it will again suffer, for the apparent efficiency of the first will be increased by its higher incandescence.

As the labor of determining the most favorable conditions for each lamp would be so great as to necessarily throw that method out of consideration, the jury felt constrained to adopt the last of the three methods mentioned above. The jury assumed, in fact, that the exhibiters of the different systems had already determined these favorable conditions in their own interest; and that in putting their lamps before the public for the entire period of the exposition, each maintaining more than two hundred lamps in different parts of the exposition building, they would operate them as nearly as possible in accordance therewith. In other words, it was decided to compare the lamps as they were used in the exhibit, determining the ratio of their illuminating-power, and measuring the electrical energy consumed by each. It is proper to state, that the lamps of both systems were spoken of by their respective representatives as sixteen candle-power lamps, although certain marks on the lamps which were supposed by the jury to refer to candle-power did not exactly agree.

To secure impartiality of selection, the jury requested permission to have access to the supply of lamps kept by each company for use in the exhibit, which permission was freely granted. From each, ten or twelve were selected at random, and carried to the testing-room; and from these the lamps which were compared were taken. They were placed upon the photometer-bar at a distance of a hundred and twenty-five inches from each other, and a system of switches was arranged, so that the galvanometers could be quickly connected with one or the other. Measures of current and electromotive force were made

rapidly and continuously during the photometric comparison.

Neither of the two lamps under test illuminated equally in all directions. They were therefore compared in nine different positions, each lamp assuming three, which were designated respectively, 'flat,' 'edgewise,' and 'forty-five degrees;' and each position of one was compared with all of the other. Five sets of readings were made at each position, making, in all, forty-five comparisons of the two lamps. A number of preliminary comparisons were made, which were not considered as forming a part of the actual test. The latter was made on the evening of Sept. 29.

The determination of the efficiency of the dynamos consisted in measuring the power consumed, as shown by the dynamometer, on the cradle of which the dynamo was placed, and at the same time measuring the current and the electromotive force at the binding-posts of the machine. The speed of the main shaft being nearly uniform, it was necessary to place different pulleys upon it, in order to secure the necessary speed for the armatures of the different machines. The speed of running being a matter which concerned the exhibiters rather than the jury, they were requested to furnish the dimensions of these pulleys, and accordingly did so. The average speed of the armature of the Weston dynamo for incandescent lamps was a little above ten hundred and thirty revolutions per minute, during three different series of observations made while the machine was on the cradle. The Edison dynamo was placed on the cradle on the afternoon of Oct. 2, when a series of measurements was made with an average speed of ten hundred and sixty-eight revolutions. This was above what may be called the 'normal speed,' which was due partly to the size of the pulley, and partly to the fact that the engine was doing but little other work, and was probably running a little above its normal rate. In the evening the tests were continued, the speed of the armature being a little below a thousand revolutions, the electromotive force being also less. It will be observed that the 'efficiency' of this dynamo, under the latter conditions, differs from that under the former by only two-tenths of one per cent. Particular attention is called to the fact, that no photometric measurements were made with lamps on the circuit of the Edison machine, which was on the dynamometer; those used being supplied from another similar dynamo, which was run by an Armington and Sims engine, which formed a part of the Edison exhibit. A glance at the results given below will show that the electromotive force in the latter case was much lower than in the former.

Tests of the galvanometers.

Although the jury was satisfied of the accuracy of the Thomson galvanometers, within all practical limits, before deciding to rely upon their indications, for reasons that need not be referred to here, it was considered desirable, after the conclusion of the tests, to make such an examination of them as would leave no doubt as to the correctness of this opinion. The chief cause of error in these instruments, and in all of a similar construction, is the possible variation in the strength of the permanent magnets which establish the field in which the needles move. The existence of a strong field is a great advantage, as has already been pointed out, provided its value is known. An examination of the instruments was made before they were taken to Cincinnati; and then, again, when they were mounted in the testing-room, they were compared with others not liable to such alterations, as before related. Numerous tests were made to ascertain if each instrument was consistent with itself by measuring the same quantity with the magnetometer at different points of its scale, thus varying the position of the needle; and the results were satisfactory. Finally, after the instruments were returned to the physical laboratory of the Ohio state university, they were subjected to tests, a brief account of which is as follows: —

For the potential galvanometer, ten cells of the 'gravity battery,' — the elements of which were zinc, zinc sulphate, copper sulphate, and copper, — in good condition, were individually compared by the condenser method with a standard Daniell cell set up for the purpose. They differed very little among themselves; and when the electromotive force of the ten, in series, was measured by means of the Thomson instrument, the resulting electromotive force of the Daniell was 1.106 volts. The instrument was also compared with one of Ayrton and Perry's voltmeters, kindly furnished for the purpose by the Electric supply company of New-York City. For this purpose recourse was had to an Edison lighting-plant, the instruments being applied to the same lamp. The fall in potential in the lamp was at first 110 volts, which was beyond the range of the Ayrton and Perry instrument; but it was reduced a little below 100 volts, and two measurements were taken with each instrument.

The Thomson read the same in both measurements, making the electromotive force 97.6 volts. The divisions on the scale of the Ayrton and Perry were very small, making the reading quite difficult. From it were obtained, in the two measurements, 96.1 and 95.5 volts.

Assuming that the field of the potential galvanometer is known, it is easy to determine that of the current galvanometer, as the magnets are interchangeable. A series of observations was made in which a practically constant quantity was measured, first with one of these magnets on the magnetometer, and then with the other, alternating throughout the series. Twelve observations made in this way show a mean difference of 1.75% between the two magnetic fields. In the numbers used in these tests the difference is 2%.

The current galvanometer was also compared with an Ayrton and Perry ammeter at the same time at which the potential instruments were compared. The circumstances did not allow the use of a stronger current than that passing through a single Edison lamp. The result was therefore not of great value. The Thomson showed 1.05 ampères, and the Ayrton and Perry gave 1.03 for the same current.

Several tests of the current galvanometer were made by means of a battery of five Grove cells, which were freshly set up. The reading of the galvanometer was noted, and then a resistance of one ohm was introduced into the circuit. The first reading was 19, and the second was 9.5; showing that the resistance of the battery and galvanometer was one ohm. The electromotive force of the battery was then determined by means of the potential galvanometer. Two measurements were made; the first giving 9.43 volts, and the second 9.56 volts. Assuming the resistance to be one ohm, as shown above, these numbers would represent, in accordance with Ohm's law, the current in ampères. The current, as calculated from the galvanometer reading, was 9.5 ampères.

Many other tests of a similar character were made, all of which showed that the galvanometers must be admitted to be what they were assumed to be during the tests, — practically correct. But, even if they were somewhat in error, the similarity of conditions under which the competing systems were tested was such that all would be affected alike.

Results.

In determining the efficiency of the dynamos, after every thing was found to be in good order, a run of about half an hour was made; during which time readings were taken every two minutes, as nearly as could be, of the dynamometers and electrical instruments. Generally from ten to twenty sets of readings were secured. In most cases two or more 'runs' were made; the repetition being in some instances the desire of the jury, and in others of the exhibiters. Sometimes the conditions under which the dynamo was running were changed by the exhibiters, with the expectation, doubtless, of increasing its efficiency thereby. In the following summary of results, the numbers showing the electromotive force, current strength, power consumed, etc., are means of a number of observations.

Photometry of arc-lamps.

The table on the next page shows the results of the photometric comparison of the two arc-lamps, and will be easily understood. The arrows show the direction of the light measured in each series: thus, ← means a horizontal measurement; ↖ means that the measurement was of the light going upward at an angle of forty-five degrees; and ↙ refers to the light going downward at an angle of forty-five degrees. For convenience, the intensity in terms of the standard (an Edison incandescent lamp) is multiplied by 1,000 before dividing by the number of Watts.

It will be seen that the different lamps differed from each other considerably in their efficiency. This was especially true of the Weston lamp, which was irregular in its ac-

Efficiency of dynamos.

	Thomson-Houston dynamo for arc lighting.		Weston dynamo for arc lighting.	Weston dynamo for incandescent lighting.			Edison dynamo for incandescent lighting.	
	Sept. 25.	Sept. 26.	Sept. 28.	Sept. 29.			Oct. 2.	
Electromotive force, in volts	1232.0	1175.0	626.0	69.2	60.0	65.0	124.9	122.8
Current in ampères	10.03	10.08	20.3	168.1	145.7	157.4	124.7	119.3
Electrical horse-power	16.6	15.9	17.0	15.6	11.7	13.7	20.9	19.6
Horse-power consumed	19.32	20.59	19.75	18.55	12.8	15.5	21.96	20.64
Percentage of efficiency	85.9	77.2	86.5	84.1	91.4	88.4	95.2	95.0

Arc-lamps.

Thomson-Houston.						Weston.					
Direction of light.	Current.	Electro-motive force.	Watts.	Intensity in terms of standard.	$\frac{1000\ I}{W}$	Direction of light.	Current.	Electro-motive force.	Watts.	Intensity in terms of standard.	$\frac{1000\ I}{W}$
←	10.2	45.9	467	16.2	34.7	←	20.7	23.9	495	25.9	52.4
↖	10.2	46.7	475	13.2	27.8	↖	20.1	23.3	469	17.6	37.4
↙	10.2	46.3	471	85.0	180.3	↙	19.8	21.9	435	32.3	74.4
Other lamps.											
←	10.1	46.1	465	18.0	38.8	←	20.0	25.6	512	30.7	59.9
↙	10.2	46.3	474	98.8	209.0	↙	20.8	25.0	522	51.7	99.2
Means.											
←	–	–	–	17.1	36.7	←	–	–	–	28.3	56.1
↖	–	–	–	13.2	27.8	↖	–	–	–	17.6	37.4
↙	–	–	–	91.9	194.6	↙	–	–	–	42.0	86.8
General means.											
	–	–	–	40.7	86.4		–	–	–	29.3	60.1

tion. The numbers under the head of 'General means' show the average light in terms of the standard, in all directions measured, and the relative illuminating-power per unit of energy. There is a difference of more than forty per cent in favor of the Thomson-Houston.

Photometry of incandescent lamps.

The table below, showing the results of the photometric comparison of the incandescent lamps, will need but little explanation. In the first column the relative position of the carbon filaments is shown: thus, | | means that they were parallel to each other, and at right angles to the photometer-bar. The three positions of a lamp were designated as 'flat' (|), 'edgewise' (—), and 'forty-five degrees' (╲ or ╱). $\frac{W_E}{W_M}$ denotes the Watts of the Edison divided by the Watts of the Maxim. The column headed $\frac{E}{M}$ shows the actual illuminating-power of the Edison, compared with the Maxim as a unit; and the numbers are the squares of the ratios of their respective distances from the photometer-box. The numbers in this column, divided by those in the one preceding, give the numbers in the last column, headed $\frac{E_E}{M_E}$, or the

Incandescent lamps.

Position.		Edison.			Maxim.			$\frac{W_E}{W_M}$	$\frac{E}{M}$	$\frac{E_E}{M_E}$
Edison.	Maxim.	Current.	Electrom. force.	Watts.	Current.	Electrom. force.	Watts.			
|	|	.648	113.0	73.2	.887	63.7	56.5	1.30	1.11	.855
╱	|	.639	114.7	72.5	.887	64.5	57.2	1.26	1.13	.891
—	|	.636	114.6	72.9	.870	61.8	53.7	1.36	1.28	.941
—	╲	.622	115.4	71.8	.853	62.2	53.0	1.35	1.65	1.22
—	—	.631	115.4	72.8	.853	61.4	52.3	1.39	4.58	3.29
╱	—	.631	116.1	73.3	.887	63.0	55.8	1.31	3.96	3.02
|	—	.631	115.7	73.0	.870	62.6	54.4	1.34	3.74	2.79
|	╲	.639	116.5	74.5	.887	63.0	55.8	1.33	1.35	1.02
╱	╲	.648	114.7	73.5	.853	62.6	53.4	1.38	1.66	1.21

light from the Edison per unit of energy as compared with the Maxim.

The results of these comparisons in nine different positions make it possible to establish certain comparison equations, from which means may be obtained which will serve to eliminate, to some extent, the errors of experiment.

Let a = the light from the Maxim lamp 'edgewise;' then, by working through the different positions of the Edison, the above results give —

Maxim	—	a	a	a
	/	$2.77a$	$2.39a$	$2.77a$
	|	$3.58a$	$3.50a$	$3.37a$

and for means —

Maxim	—	a
	/	$2.64a$
	|	$3.48a$

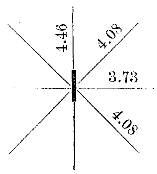
By a similar computation it is found that—

Edison	—	$4.58a$	$4.45a$	$4.36a$
	/	$3.96a$	$3.93a$	$4.38a$
	|	$3.74a$	$3.58a$	$3.86a$

the means of which give —

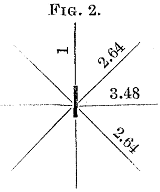
Edison	—	$4.46a$
	/	$4.08a$
	|	$3.73a$

Fig. 1.



Edison.

Fig. 2.



Maxim.

Figs. 1 and 2 show the arrangement of these intensities of illumination around the carbon filament; the plane of the filament being vertical, and Maxim edgewise being taken as unity.

For the mean all round, the result is —

$$\text{Edison} = 4.09 \qquad \text{Maxim} = 2.44$$

$$\frac{4.09}{2.44} = 1.676 = \frac{\text{E}}{\text{M}} \text{ in light.}$$

But from the previous table,

$$1.336 = \frac{\text{E}}{\text{M}} \text{ in energy:}$$

therefore $\frac{1.676}{1.336} = 1.25 = \frac{\text{E}}{\text{M}}$ *in light per electrical horse-power.*

It seems evident that this difference of twenty-five per cent in favor of the Edison lamp is largely due to the form of the incandescent filament as compared with that of the Maxim lamp. The latter shows great inequality in illumination in different directions, the light measured from the flat side being about three and one-half times as great as that obtained when the lamp is edgewise. The effect of this increased radiating surface is shown in the last column of the above table, from which it appears, that in the comparison of the Maxim, 'flat,' with the Edison in all positions, the former shows a higher actual efficiency than the latter. If this large radiating surface could be made to distribute its effect around the circumference, the lamp would, in the opinion of many, be greatly improved. It is fair to say, however, that the unequal distribution of light is claimed, by at least some of the representatives of this lamp, to be an important advantage. It was not so considered by the jury.

The form of the carbon filament in the Edison lamp is such that a much greater uniformity of illumination results. While the Maxim form has the advantage of concentrating the radiating surface, the arrangement of the carbon to accomplish this greatly diminishes its effectiveness in the 'edgewise' position. In the Edison there is but a single loop; and, furthermore, this is generally curved, so that it does not lie in one plane. As a result, one side of the loop never exactly hides the other, and there is but little loss from that source. It will be seen in the above figure that the illuminating-power of the lamp edgewise actually exceeded that in any other direction. This difference was too constant and too great to be attributed to error in experiment. It is attributable, no doubt, to the fact, that in this position the luminous lines lie nearly in the axis of the pear-shaped glass containing them, as viewed from the photometer-box; there being, therefore, less scattering of the light in transmission, and possibly some gain on account of reflection. Of course, if a lamp were used in which one of the branches of the loop exactly or nearly covered the other in this position, a different ratio of illumination might follow.

Throughout the entire series of tests the jury was fortunate in having the assistance of Mr. A. L. Rohrer, a student in physics in the Ohio state university.

In the distribution of work, Mr. Eddy and Mr. Laidlaw made the observations, and kept the records of the dynamometer work; Mr. Laidlaw also taking and reducing the indicator-cards. Mr. French made the readings of the position of the photometer-box, and set the same. Mr. Mendenhall generally read one of the galvanometers, and Mr. Rohrer the other; the latter generally keeping the notes of the electrical work, although this was done on several occasions by Mr. French and by Mr. Laidlaw.

The results of these tests seem to point to one conclusion of very considerable interest. It happened that the competition in both the arc and incandescent systems was between low electromotive force and great strength of current, on the one hand, and high electromotive force, with weaker current, on the other. In one arc system the electromotive force was almost exactly double, and the current almost exactly half, that of the other. In the incandescent systems, the contrast, although not so great, was very marked. In these trials the advantage was decidedly on the side of high electromotive force.

NOTES ON THE VOLCANIC ERUPTION OF MOUNT ST. AUGUSTIN, ALASKA, OCT. 6, 1883.[1]

On the western side of the entrance to Cook's Inlet (forty-five miles wide) lies Cape Douglas; and to the northward of the cape the shore recedes over twenty miles, forming the Bay of Kamishak. In the northern part of this bay lies the Island of Chernaboura ('black-brown'), otherwise called Augustin Island. It is eight or nine miles in diameter, and near its north-eastern part rises to a peak called by Cook, Mount St. Augustin. As laid down by Tebenkoff, the island is nearly round. The northern shores are high, rocky, and forbidding, and are bordered by vast numbers of rocks and hidden dangers. The southern shore is comparatively low.

Mount St. Augustin was discovered and named by Capt. Cook, May 26, 1778; and he describes it as having 'a conical figure, and of very considerable height.' In 1794 Puget describes it as

> "A very remarkable mountain, rising with a uniform ascent from the shores to its lofty summit, which is nearly perpendicular to the centre of the island, inclining somewhat to its eastern side. . . . Towards the seaside it is very low, from whence it rises, though regular, with a rather steep ascent, and forms a lofty, uniform, and conical mountain, presenting nearly the same appearance from every point of view, and clothed with snow and ice, through which neither tree nor shrub were seen to protrude; so that, if it did produce any, they must either have been very small, or the snow must have been sufficiently deep to have concealed them."

At that time there were native hunters, under the direction of two Russians, hunting or living in the vicinity of the north-eastern point of the island.

Vancouver placed the peak of this mountain in latitude 59° 22′: Tebenkoff places it in latitude 59° 24′.

The peak of St. Augustin is distant forty-nine miles nearly due west (true) from the settlement on the southern point of Port Graham, or, as it is sometimes called, English Harbor. This harbor is situated on the eastern side of Cook's Inlet, near Cape Elizabeth.

In connection with the fall of pumice-dust at Iliuliuk on Oct. 16, 1883, it may be of interest to observe, that the peak of Augustin is over seven hundred miles to the north-eastward of Bogosloff Island, off Unalashka (see map).

About eight o'clock on the morning of Oct. 6, 1883, the weather being beautifully clear, the wind light from the south-westward (compass), and the tide at dead low water, the settlers and fishing-parties at English Harbor heard a heavy report to windward (Augustin bearing south-west by west three-fourths west by compass). So clear was the atmosphere that the opposite or north-western coast of the inlet was in clear view at a distance of more than sixty miles.

When the heavy explosion was heard, vast and dense volumes of smoke were seen rolling out of the summit of St. Augustin, and moving to the north-eastward (or up the inlet) under the influence of the lower stratum of wind; and, at the same time (according to the statements of a hunting-party of natives in Kamishak Bay), a column of white vapor arose from the sea near the island, slowly ascending, and gradually blending with the clouds. The sea was also greatly agitated and boiling, making it impossible for boats to land upon or to leave the island.

From English Harbor (Port Graham) it was noticed that the columns of smoke, as they gradually rose, spread over the visible heavens, and obscured the sky, doubtless under the influence of a higher current (probably north or north-east). Fine pumice-dust soon began to fall, but gently, some of it being very fine, and some very soft, without grit.

At about twenty-five minutes past eight A.M., or twenty-five minutes after the great eruption, a great 'earthquake wave,' estimated as from twenty-five to thirty feet high, came upon Port Graham like a wall of water. It carried off all the fishing-boats from the point, and deluged the houses. This was followed, at intervals of about five minutes, by two other large waves, estimated at eighteen and fifteen feet; and during the day several large and irregular waves came into the harbor. The first wave took all the boats into the harbor, the receding wave swept them back again to the inlet,

[1] Communicated by Prof. J. E. Hilgard, superintendent U. S. coast and geodetic survey.